The Hiding Power of White Pigments and Paints

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The Hiding Power of White Pigments and Paints

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With a Discussion on Applications of the

Hiding Power-Brightness Relationship in Comparing White Pigments and Paints

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The Hiding Power of White Pigments and Paints

By A. H. Pfund, Ph.D.
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THE hiding power of a paint may be defined as that property of a paint which enables it to obliterate beyond recognition any background upon which it may be spread. In order to compare the hiding power of two white pigments, the almost universal custom is to rub down equal masses of the two samples with the same amount of linseed oil and ultramarine blue. The resultant pastes are spread side by side and the sample which has the paler tint is supposed to contain the pigment of greater hiding power. The idea is that the particles of white pigment hide the dark particles and hence give a light tint to the paste. As a result of the experiments to be described presently, it appears that the criterion, upon which the above tests are based, is incorrect.

The object of this investigation is to present a method which will yield numerical values of the true hiding power of white pigments and paints. The basic idea underlying the discussion is this: granting that an infinitely thick layer of a paint will "hide" a given background completely, it is sought to find the thinnest layer which will hide the background as effectively as does the infinitely thick layer. Obviously, the thinner the layer of paint required, the greater is the hiding power of the paint. For white paints, the severest test met with in practice is a white wall with black lettering. It is desired to obliterate the lettering by covering the entire surface with successive coats of paint. These conditions are simulated in the instrument about to be described.

The form given the instrument is shown in Fig. 1. Here, A is a plate of glass, 14 x 5 x .6 cm., whose upper surface is optically flat. The lower surface is coated with black baking enamel, which yields the desired black background. A transverse groove, B, about 2 mm. deep and 1 cm. wide, is cut in the upper surface and a millimetre scale is etched, as shown in the drawing. Resting upon plate A is plate C (7 x 3.5 x .6 cm.), whose lower surface is likewise optically flat. A strip of thin steel, D, 0.45 mm. thick, is attached to C, so that a wedge-shaped layer of white paint may be formed between the plates. This wedge terminates abruptly at the "infinitely thick" layer, B, and, so long as the hiding is not complete, the line of demarcation is visible. By sliding the wedge to the left it is finally

impossible to see the edge. From a knowledge of the angle of the wedge and the reading on the scale, it is possible to calculate the thickness of this critical layer lying immediately above the edge B. Now, in advancing the plate C until the line of demarcation can no longer be seen, we have overdone it, so to speak. To correct this, we must reverse the motion of the wedge until the edge can just be distinguished over its entire length. The mean value of the reading corresponding, respectively, to disappearance and appearance of the edge, yields the desired result. Since the

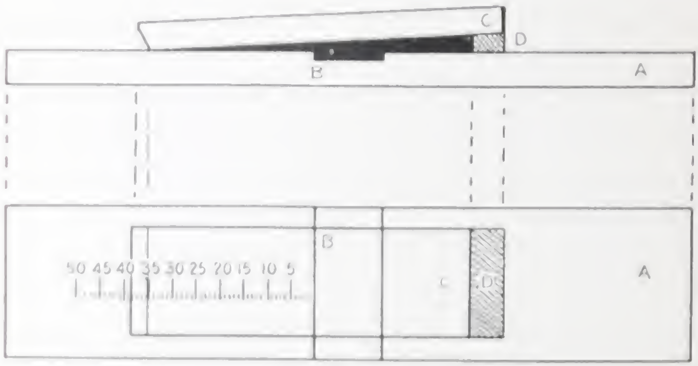

Fig. 1

fading away and reappearance is so gradual, due to the fact that the least perceptible increment of intensity which the human eye can detect is 1 to 2 per cent. (Fechner's Law), it is clear that no high degree of precision is attainable by this method. By taking ten pairs of readings it is found that the average deviation from the mean is about 3 to 4 per cent.

A suitable viewing device has been found necessary since the reflection of the observer's face in the plate C is annoying. An advantageous arrangement is shown in Fig. 2, where strong daylight illuminates the apparatus from the observer's right (or left). The essentials of the device are, a blackened board, G, about 30 cm. above the apparatus, with suitable openings for the eyes, I, and a vertical blackened shield, H. The entire instrument is to be called "Cryptometer."[1]

If it should ever become necessary to develop the instrument so as to yield results of high precision it will always be possible to do so. The two methods which suggest themselves are: (1) if we call the hiding complete when the brightness of the variable layer is 99 per cent. of that

[1]I am indebted to Mr. H. Green for suggesting this name.

of the infinitely thick layer, then, by means of a photo-electric cell, which measures the light from the two layers in contact at the edge B (Fig. 1), it will be possible to locate the desired point very accurately; (2) by making, preliminarily, a study of the variation of brightness of the paint with increasing thickness, a formula may be established connecting these two quantities; then, by finding a position of the wedge where the brightness is, say, one-half that of the infinitely thick layer, it is possible to calculate

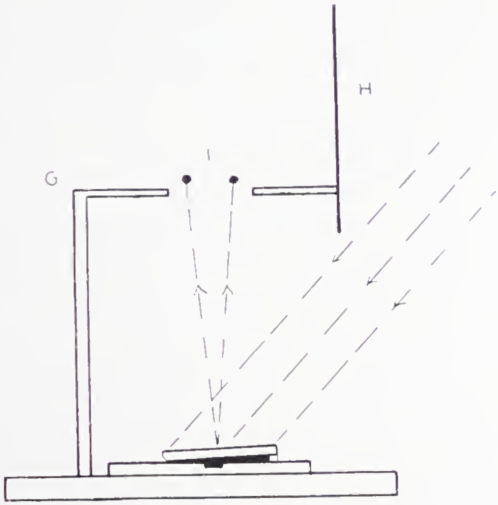

Fig. 2

the thickness yielding 99 per cent. of the brightness of the infinitely thick layer. These methods have not been developed for the reason that the cryptometer in its present form is not only sufficiently accurate for most purposes, but is extremely simple in its construction and operation.

A sharp distinction must be made between the hiding power of a pigment and that of a paint. Not only are these quantities expressed in different units, but they are not necessarily related in the sense that a pigment of great hiding power necessarily produces a paint of correspondingly great hiding power. Taking up first the hiding power of pigments, let us consider an intimate mixture of x grs. of a white pigment and y grs. of colorless (or very pale) linseed oil. This mixture is tested in the cryptometer and the critical thickness producing complete hiding is found.

Let

t = thickness of critical layer (in cms.).
b = numbers of grs. of pigment in a disc of 1 cm.² base and thickness t.

Then, if b grs. pigment hide I sq. cm., we find the number of sq. cm. A covered and hidden by I gr. of pigment from the relation

$$b : I :: I : A \text{ or } \frac{I}{b} = A.$$

Since the hiding power is better the thinner the layer, i.e., smaller than b, we may define the hiding power of a pigment as the reciprocal of the number of grs. of pigment, mixed with colorless linseed oil to painting consistency, which are necessary to hide a black, non-absorbent area I cm². This is numerically equal to the number of square centimetres covered and hidden by I gr. of pigment. Hiding powers of pigments will, therefore, be expressed in terms of cm.² per gr. Experiment has shown that the hiding power of the pigment is affected by the relative amount of oil present—the thinner the mixture, the greater the hiding power. This means that the hiding power is not only a function of the number of white particles, but also of their separation. In order to reduce all mixtures to a standard condition, the terms "painting consistency" are specified in the above definition. Data will be presented later.

Turning next to the hiding powers of paints, we choose, as a measure, the number of square feet which one gallon of paint will cover and hide. While the retention of the metric system might, at first thought, seem advisable, practice dictates the selection of the English system of units. The actual measurements and calculations are very simple. The paint is measured up in the cryptometer and, from a knowledge of the critical thickness the number of square feet per gallon is calculated at once. As a matter of fact, cryptometers are now made so that one may read the result directly off a separate scale etched on the lower plate.

The results obtained for characteristic pigments and paints are summarized in the following table.

Pigment.	Grs. Pigment / Grs. Oil.	Hiding-power Pigment. cm.²/gr.	Hiding-power Paint. sq. ft./gal.
1. Sublimed white lead	7:3	26	172
2. Basic carbonate white lead	7:3	36	243
3. Lithopone	4:3	51	190
4. Titanium oxide	3:4	58	132
5. Zinc oxide (leaded)	1:1	59	194
6. Zinc oxide (pure)	3:4	57	145
7. Zinc oxide plus trace of lamp black	3:4	190	486

Concerning the pigments themselves, the results obtained speak for themselves. The theory of hiding power as dependent on particle size, wave-length of light, character of vehicle, etc., will be taken up in a separate paper. The one point, however, to which attention must be called, is that involving a comparison of pigments 6 and 7. The only difference between these two pigments is that 6 is white while 7 is pearl gray. If these same pigments are compared by rubbing them down with oil and ultramarine blue, the gray sample will show the darker tint; hence it will be considered as having a smaller hiding power than the white sample. As a matter of fact, the hiding power of the gray sample is more than three times as great as that of the white. In a paper describing a new colorimeter,[1] it will be shown that all paints are more or less gray. It is, therefore, clear that, since the rubdown test yields results which are violently at variance with those obtained with the cryptometer, the former method must be discarded.

The results on paints are interesting. While the hiding powers of zinc pigments are larger than those of the white leads, the reverse is true of the paints. (Compare samples 2 and 6.) The reason is obvious when the "oil absorption" of the pigments is considered. One pound of zinc oxide mixed with one pound of linseed oil yields a mixture of proper painting consistency, while a similar mixture of white lead in oil is entirely too "runny" for painting purposes. More lead must be added to give the correct "body" or thickening to the paint. Such a paint has the greater hiding power, but it has gained its superiority in consequence of the excess of lead pigment which has been added.

While ideal conditions exist in the cryptometer tests, it seemed of interest to compare the results thus found with those obtained in actual painting practice. I am indebted to Mr. R. J. Hauk for preparing the paints and carrying out the painting tests. Briefly, the experiment consisted in preparing three zinc paints (pigment ground in linseed oil). Three clapboard panels, having an area of 3.75 square feet, were well primed with white paint. A cross of black paint was applied to each of these surfaces and the whole was allowed to dry. Then successive coats of the respective paints were applied until the black cross could no longer be seen. From a knowledge of the area painted and the volume of paint consumed in each case it was possible to calculate the number of square feet per gallon which the respective paints would cover and hide. These tests extended over a week or more. When about half the adequate number of coats had been applied, the writer made hiding-power tests with the cryptometer. The results were as follows:

[1]Presented at the fall meeting of the National Academy of Sciences, Baltimore, 1918; also at meeting of the Optical Society, Baltimore, December 28, 1918.

Paint.		No. of Coats	Hiding-power Painting Test. sq. ft./gal.	Hiding-power Cryptometer. sq. ft./gal.
1. ZnO (heavily leaded)	63.2 per cent.	6	225	256
Vehicle	36.8 per cent.			
2. ZnO (less heavily leaded)	52.7 per cent.	7	204	213
Vehicle	47.3 per cent.			
3. ZnO (pure)	48.6 per cent.	9	150	150
Vehicle	51.4 per cent.			

On the whole, the agreement is quite good. The findings of the painting test will always be the smaller for two reasons:

1. Brush marks will leave thin places which must be covered up.

2. Only whole numbers of coats may be applied, i. e., if theoretically 6.4 coats would just hide the black cross it is unavoidable that 7 coats be applied. Obviously, the greater the number of coats, the closer is the approach to the ideal conditions which are realized in the cryptometer.

The conclusion to be drawn from these experiments is that the true hiding power of a paint may be obtained in a very few minutes by means of the cryptometer.

It is clear that if a surface of lighter tint (say, white pine) is to be hidden, the number of square feet per gallon will be considerably larger. The cryptometer must necessarily leave out of consideration the absorption of the paint in the pores of the wood. However, this instrument may be adapted to take care of lighter backgrounds by removing the black paint from the lower surface of plate (A), Fig. 1. If this plate be rested on the actual surface to be painted, it is again possible to determine in advance just how many gallons are required to paint a given area.

The principal purpose of this discussion is to present the cryptometer rather than final values of the hiding power of pigment and paints. In order to realize the latter, it will be necessary to grind the pigments in oil and to formulate a rigorous definition of, and test for, "painting consistency."

The results obtained may be summarized as follows:

1. An instrument which yields numerical values of the hiding powers of pigments and paints has been devised.

2. A table of true hiding powers of characteristic pigments and paints is presented.

3. A comparison of actual painting and cryptometer tests shows that the two are essentially in agreement.

(This work was carried out partly at the Johns Hopkins University and partly at the Research Laboratory of The New Jersey Zinc Co.)

(Reprinted from the "Journal of the Franklin Institute.")

DISCUSSION

OF THE

Application of Hiding Power—Brightness Relationship in Comparing White Pigments and Paints

By H. A. Nelson, M. A. and G. F. A. Stutz, Ch. E.

SINCE the publication of the preceding Research Bulletin on this subject, further investigation[1] has established a useful relationship between the brightness and hiding power characteristics of white pigments. This work indicates that within the range of the brightnesses of the commercially produced white pigments, which is from 70% to 90% brightness, the brightness-hiding power relationship is practically linear, and that this line, if projected to the origin, cuts the axes very nearly at the theoretical point, 100% brightness—0 hiding power.[2]

The practical advantage of this, as pointed out in the original investigation, is the ease with which commercial white pigments (and their paint combinations) may be compared on a basis of equal brightness. It is, then, only necessary to make observations for both brightness and hiding power on the samples in question. If these are plotted, and a line projected from this point to the region of the point 100% brightness —0 hiding power, comparisons may be made at desired brightnesses.

Experimental Results on Pigments

Fig. 1, showing this relationship on a basis of hiding power in sq. cm. per gram of pigment, is taken from the original paper. The data are for the pigments alone ground with pale linseed oil without turpentine or dryer added. The circled dots are the readings as taken on the original pigments. The crosses are the readings obtained by Pfund when the brightnesses were cut down with bone black, and illustrate the nature of the brightness-hiding power relationship referred to above.

Reference to the following figures and tables will show at a glance what erroneous conclusions as to the relative merits of pigments may be arrived at by confining the observations to hiding powers alone.

[1] A. H. Pfund, Journal of The Franklin Institute, July, 1923.
[2] The reader is referred to the original paper for a more detailed discussion of the exact form for this curve.

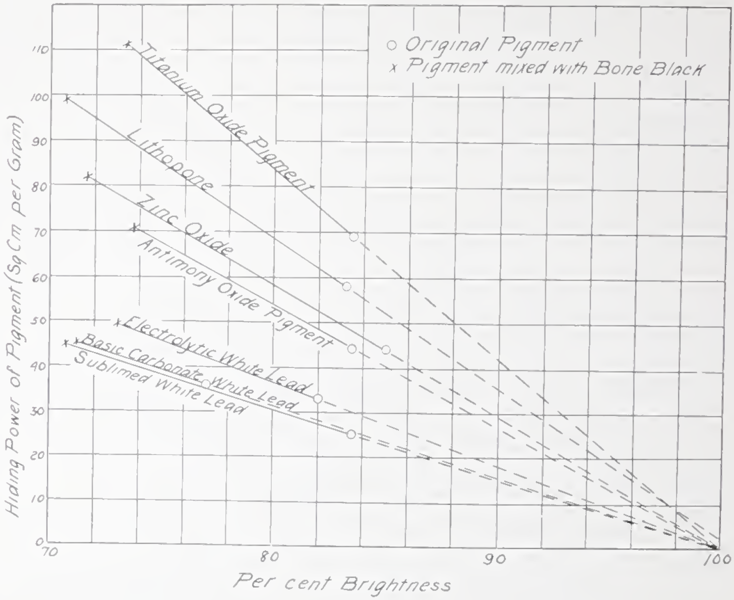

Fig. 1

Hiding power-brightness relationship for white paints, as determined by Pfund. (Journal of the Franklin Institute, July, 1923).

In Table I and Figure 2 are shown the hiding power-brightness values for the most recent samples of the several white pigments obtainable in March 1926. In each case the pigments were rubbed in pale (almost colorless) linseed oil.

The higher brightnesses given in Figure 2 as compared with Figure 1 may be due to three factors, first, improvements in the manufacture of the pigments used, second, difference in the oil used in making the pastes, and third, differences in the calibration of the instruments used.

Two standards for comparison appear in Table I. They are: (1) the original samples as observed; (2) at a calculated brightness of 80%, which is sufficiently low to be easily attained by any clean pigment which is sufficiently white to be classed as a white pigment.

Experimental Results on Prepared Paints

The same relationships may be used in comparing paints at painting consistency. It should be noted, however, that because of the varying amounts of vehicle required with different pigments to attain painting

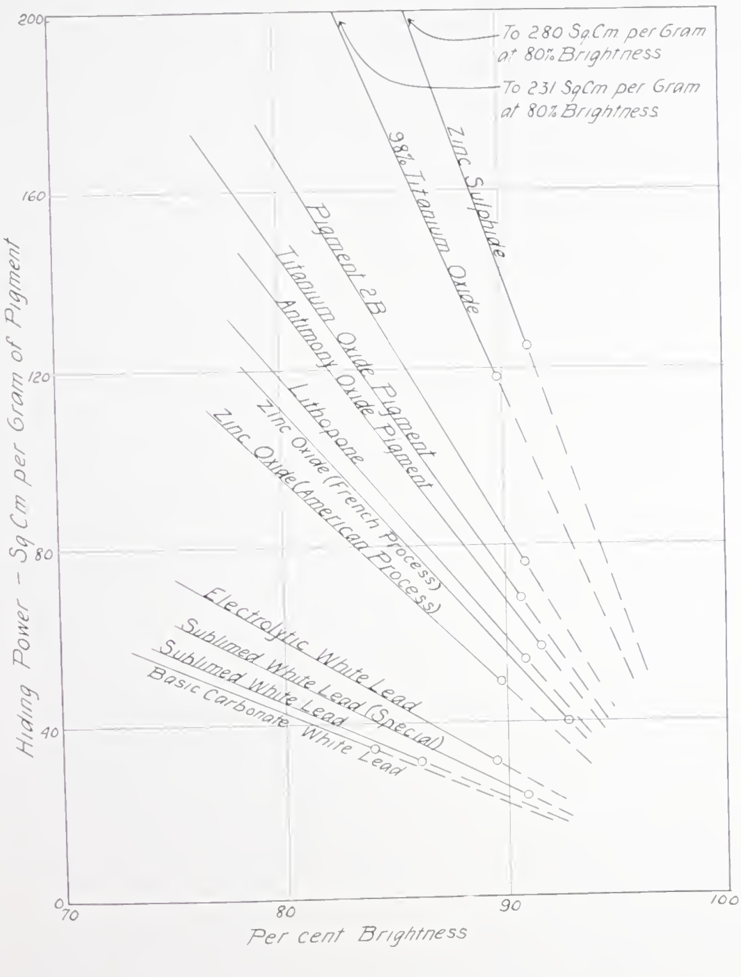

Fig. 2

Hiding power-brightness values of white pigments as determined in a vehicle consisting of pale refined linseed oil. (See Table I).

TABLE I

Table Showing How Pigment Hiding Powers (CM^2 per Gram of Pigment) are Affected When Reduced to a Single Standard of Brightness

Pigment	Per cent Linseed Oil in Mixture (by weight)	Percentage Brightness of Sample	Hiding Power of Sample CM^2 per Gram	Hiding Power All Pigments Reduced to 80% Brightness CM^2 per Gram	Change in Hiding Power CM^2 per Gram	Per cent Increase or Decrease from Sample
B. C. W. Lead	50	81	31	12	+ 8	+ 23
S. W. Lead	50	86.1	31	44	+ 13	+ 42
S. W. Lead, special	50	90.9	23	50	+ 27	+117
Elec. W. Lead	50	89.5	31	59	+ 28	+ 90
Zinc Oxide (American Process)	50	89.8	49	97	+ 48	+ 98
Zinc Oxide (French Process)	50	92.8	40	111	+ 71	+177
Lithopone	50	90.9	51	118	+ 64	+119
Antimony Oxide Pigment	50	91.6	57	136	+ 79	+138
Titanium Oxide Pigment	50	90.7	68	147	+ 79	+116
Cryptone	50	90.9	76	168	+ 92	+121
98% Titanium Oxide	60*	89.8	118	231	+113	+ 96
Zinc Sulphide	50	91.2	124	280	+156	+126

*In order to handle this pigment on the cryptometer, it was necessary to use 60 per cent vehicle.

consistency, the hiding powers of the paints may or may not hold the same relative order of magnitude as for the pigments themselves.

A number of representative paints purchased in the open market, and others prepared in the laboratory, were compared for hiding power and brightness. Hiding powers were measured on an improved cryptometer which will be described in another place (see Fig. 6).

Brightness measurements were made with the Pfund colorimeter[3] on the wet paints as applied on a steel colorimeter plate. The readings are for green light ($\lambda = 560$), which gives essentially the same results as white light, and enables the operator to take readings more easily and accurately.

The maximum variation observed for the cryptometer readings was $\pm$ 6%. Generally the readings checked within $\pm$ 3%. A maximum variation of $\pm$ 5% is the limit observed for a large number of readings taken in the course of routine examinations of paints by this Laboratory.

Averages for brightness measurements, by two operators, checked within $\pm$ 0.2% except in one case where the variation was $\pm$ 0.4%.

The compositions of the paints in question, together with the observed values for hiding power and brightness, and the comparative hiding powers at a standard brightness (80%) are summarized in Tables II, III, and IV.

The values for hiding powers at brightnesses other than the observed brightnesses for the samples, were obtained by extrapolation along the lines drawn from the observed point to the region 100% brightness—0 hiding power, in the manner previously explained. These are plotted in Figs. 3, 4 and 5. The selection of a single standard of brightness at which comparisons are to be made would be desirable. The somewhat different brightness ranges of the different types of paints also suggests that a standard might be selected for each type. For example, 85% apparently is a relatively high brightness for an outside paint but a low standard for enamels, and also comparatively low for high grade flat whites.

However, in the original report it has been indicated that it is not entirely practicable to extrapolate toward higher brightnesses because certain pigments may already be essentially "clean" at the brightness observed. In order then to obtain higher brightnesses the physical properties of the pigment itself (particle size, etc.), must be changed. This would give rise to what is essentially a new pigment with a brightness-hiding power curve of its own. In order to overcome this possible objection, a standard brightness has been selected for these comparisons which is so low that all pigments classed as white may be expected to attain the standard. The value thus suggested as a standard for comparison is 80% brightness.

[3] Pfund, "The Colorimetry of Nearly White Surfaces," J. Frank. Inst., March, 1920.

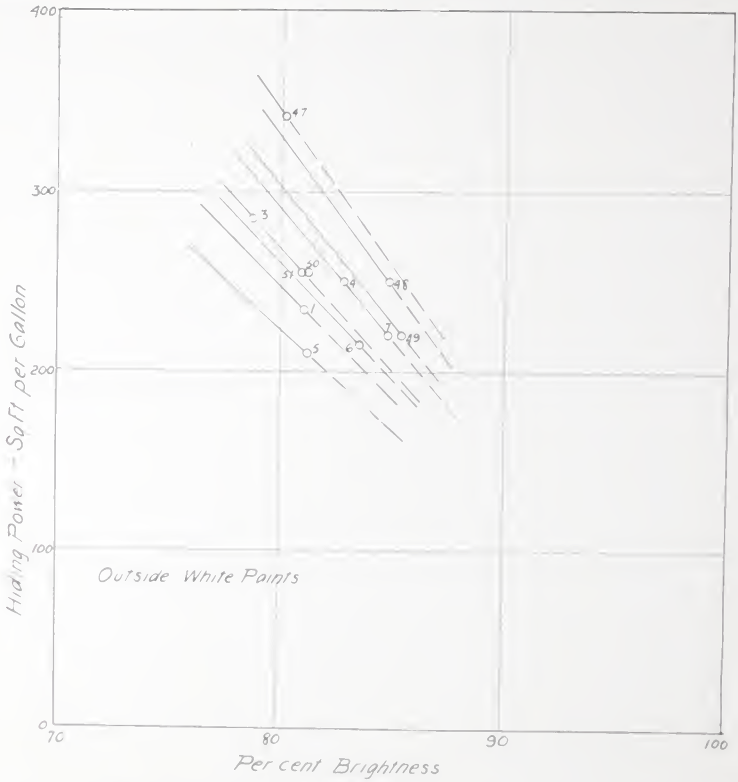

Fig. 3
Hiding power-brightness values for outside white paints.
(See Table II).

While the general nature of the results is quite evident from the tables and figures which are shown, certain points concerning each type of paint may be profitably emphasized.

Outside White Paints

The hiding power of the average commercial outside white paint (Fig. 3 and Table II) apparently falls in the region 220-250 sq. ft./gal. This coincides quite well with the average results of a large number of observations made in the course of routine laboratory examinations of white paints as they appear on the market.

The average range of brightnesses for such paints is apparently from 81 to 85 per cent.

TABLE II

Outside White Paints

Sample	Source	Percentage Composition (by weight)										Observed Values		Calculated Hiding Power at 80% Brightness, Sq. Ft./Gal.
		Zinc Oxide	Litho-pone	Basic Car-bonate White Lead	Su-blimed White Lead	Mag-nesium Silicate	Barytes	Silex	Per cent Vehicle in Paint	Per cent Volatile in Vehicle*	Weight Lbs./Gal.	Per cent Bright-ness	Hiding Power Sq. Ft./Gal.	
47	Commercial	39	40	..	..	21	..	..	31.7	6	16.2	80.1	340	340
48	Commercial	40	40	..	..	10	..	10	38.5	9.1	14.7	84.8	250	330
49	Commercial	37	42	..	..	15	6	..	38.7	10.6	14.7	85.1	220	300
7	Commercial	25	..	56	19	..	..	..	36.1	5	17.0	81.8	220	290
1	Commercial	18	..	52	..	..	..	..	40.9	5.1	15.6	82.8	250	290
50	Commercial	38	12	..	..	10	..	10	40	8.0	11.2	81.2	255	270
3	Commercial	..	..	100	..	..	..	..	27.5	9	19.5	78.7	285	270
51	Commercial	43	38	..	..	..	10	9	40	11	14.1	80.9	255	265
6	Commercial	57**	..	..	..	21	22	..	38.8	36	14.2	83.5	215	260
1	Laboratory	100	..	..	..	..	..	..	45.5	9	13.8	81.0	235	250
5	Commercial	34	..	27	27	11	..	..	31.1	8.3	17.6	81.2	210	220

* Including volatile in liquid dryers.
** 35% leaded zinc oxide.

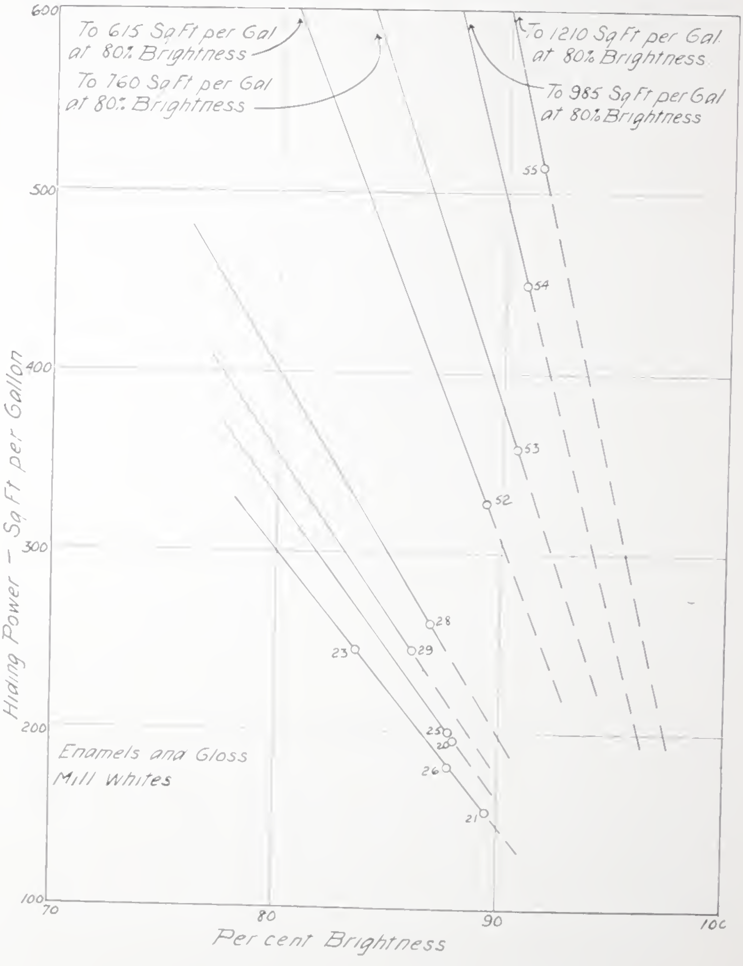

Fig. 5

Hiding power-brightness values for enamels and gloss mill white paints (See Table IV)

TABLE IV

Enamels and Gloss Mill Whites

		Percentage Composition (by weight)							Observed Values		Calculated Hiding Power at 80% Brightness Sq. ft./Gal.
Sample	Source	Zinc Oxide	Lithopone	Cryptone	Zinc Sulphide	Vehicle in Paint	Volatile in Vehicle	Weight Lbs./Gal.	Per cent Brightness	Hiding Power, Sq. ft./Gal.	
20	Commercial	100	..	..	..	50	33.7	13.2	88.0	195	330
25	Commercial	100	..	..	..	51.4	30.7	13	87.3	200	330
21	Commercial	100	..	..	..	53	37.1	12.6	89.5	155	300
26	Commercial	100	..	..	..	58	32.8	12	87.8	180	300
23	Commercial	100	..	..	..	19	50	13.1	83.6	215	300
28*	Commercial	25	75	..	..	11.5	36.9	13.9	86.9	260	100
29*	Commercial	..	100	..	..	19.3	29.8	12.6	86.1	215	355
52	Laboratory	20	..	80	..	11	26.6	11.1	89.3	330	615
53	Laboratory	..	..	100	..	12	26.6	13.9	90.6	360	760
51	Laboratory	20	..	..	80	12	26.6	11.3	90.9	150	985
55	Laboratory	..	..	..	100	12	26.6	13.7	91.5	515	1210

* Gloss Mill Whites.

Flat White Paints

Paints of this type offer more immediate opportunity for the development of higher standards of brightness and obscuring power, because the pigments which can be used are not limited by serious consideration of weathering effects, such as limit the pigments available for use in exterior paints.

Aside from the beauty of a clean white surface, where white is desired, there is the added argument for a high standard of brightness. The clear color tones, so desirable for interior decoration, can only be obtained by starting with a bright base pigment.

Increased hiding power is, of course, a matter of economic importance. Wherever it can be accomplished without otherwise depreciating the quality of the painting job, the possible saving in labor between two coats of paint and three coats, or one coat and two coats (especially on repaint jobs) is a matter worthy of serious consideration both by the paint manufacturer and the consuming public.

The experimental results shown in Fig. 4 and Table III on products now being marketed, and paints prepared in the laboratory from various pigments indicate the possibilities of future developments with this type of paint, both as to increased hiding power and brightness.

Enamels and Mill Whites

In the use of white enamels, the hiding has usually been supplied by the undercoater to such an extent that brightness and gloss become the main criteria of quality for the enamel itself. However, it is evident from the data given that it has become possible to make enamels also contribute to the obscuring of the back-ground.

Description of Improved Cryptometer

By certain changes in the construction of the cryptometer[4], it has been found possible to overcome a difficulty which is met in practice when paints, containing barytes and other coarse particles, are being investigated. These coarse particles get under the areas of contact of the two cryptometer plates—hence, if the pressure on the top plate is only moderate, the coarse particles are neither crushed nor forced out and, as a result, the cryptometer reading is too low. If, on the other hand, sufficiently great pressure is exerted, the top plate is distorted and readings which are too high are obtained. Furthermore, such pressure in conjunction with sliding motion causes a grinding action which, in time, occasions a change in the wedge-constant. These difficulties have been overcome entirely by cutting deep longitudinal grooves into both upper and lower plates.

[4] Quoted from A. H. Pfund, Journal of The Franklin Institute, July 1925.

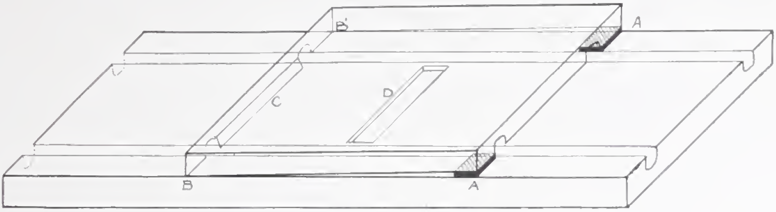

Fig. 6
Improved Type of Cryptometer

The usual metallic strip attached to the top plate is replaced by two small metallic squares at A and A'; again, the glass in the central area at C is cut away for a distance of 5 mm. When this plate is laid upon the lower one, contact is made only on the outer, narrow strips at AA' and BB'. Upon filling in the ends of the transverse groove, D, it is found that, when paint is applied to the area between the longitudinal grooves, the upper plate may be moved back and forth many times without dragging paint to the outer strips along which the plates are in contact. Needless to say, no pressure other than the weight of the top plate is now necessary. Very consistent results are obtained as a result of these modifications.